Investigating the Correlations between Magnetism, Transport, and Local Structure of Calcium Substituted Lanthanum Manganites.

Modern Computer technology hinges on the relationship between electrical and magnetic properties of materials. For the manganites, both properties are strongly dependent on small changes in the atomic spacing.

X-ray absorption spectroscopy is used to investigate the atomic structure and can detect changes to less than a thousandth of a nanometer. Figure 1 shows the distorted Lanthanum manganite ($LaMnO_3$) structure – a "kinked" cubic structure. In the undistorted state, the kinks are removed. Substituting calcium into $LaMnO_3$, produces a distribution of undistorted and distorted sites; the latter become undistorted at low temperatures. The distorted structure inhibits electron conduction and the development of magnetism.

Our results (Figure 2) suggest that for a given calcium concentration, the amount of distortion removed as the temperature is lowered depends only on the fraction of the sample magnetized. However, the shape of the curve changes with concentration (see arrows). This provides detailed information as to how magnetization develops on an atomic scale. Such detail has not been previously observed.

Figure 1

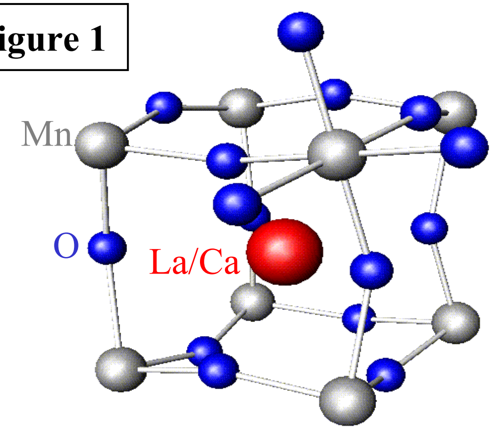
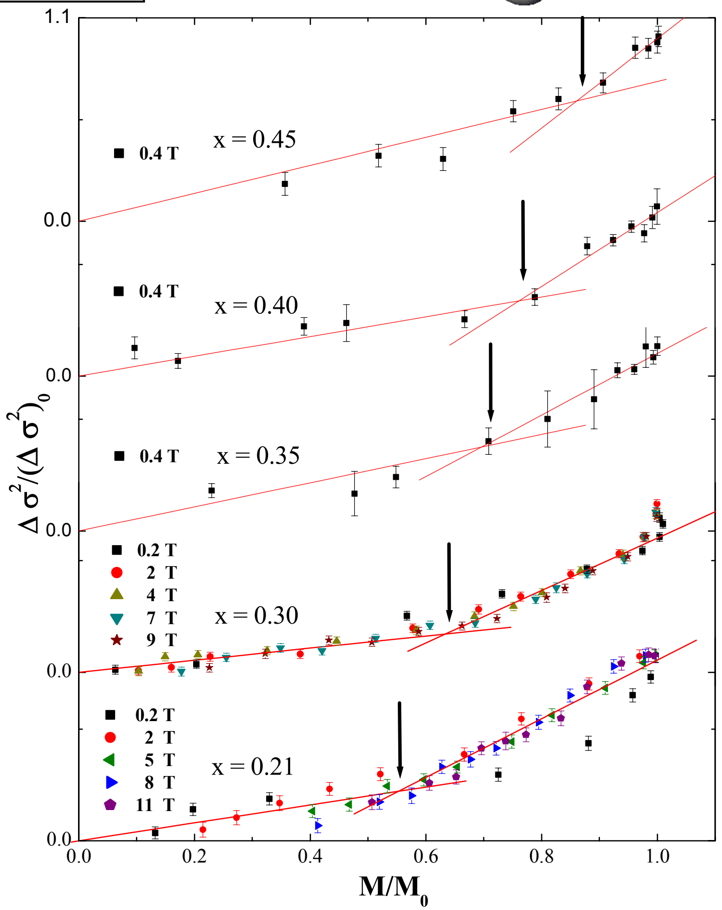


Figure 2



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Computer manufacturers are currently using giant magnetoresistors in magnetic hard-drives to store data. These devices experience a large change in resistance when a magnetic field is applied. The calcium substituted Lanthanum manganites ($La_{1-x}Ca_xMnO_3$) are colossal magnetoresistors and exhibit a much larger effect, for calcium concentrations in the range of 20% to 50%. In addition, for this class of materials, there is a clear and unusual relationship between the magnetism, atomic structure, and the electrical conductivity. These materials have the potential to improve the current technology, but first the properties must be better understood.

We are using x-ray spectroscopy to study the structure of these materials on an atomic scale; with this technique, we can detect changes to less than a thousandth of a nanometer. We have found that distortions in the atomic structure are removed as the sample becomes magnetic. The amount of distortion removed depends only on the fraction of the sample that has become magnetized, independent of whether the temperature or an applied magnetic field is changed. This unusual relationship leads to a model for the magnetization, in which the magnetized regions initially develop in spaghetti-like filaments throughout the sample.

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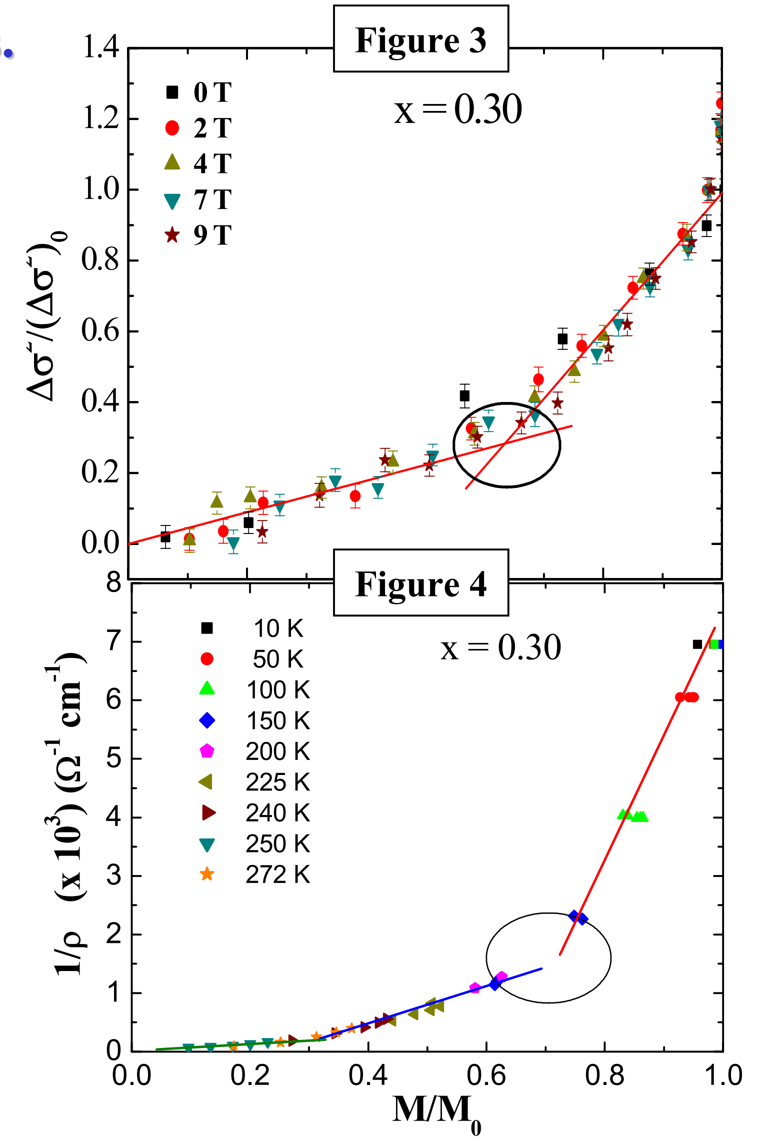
Broader implications

In Figures 3 and 4, we compare changes in the atomic distortions (Fig. 3) with changes in electrical conductivity (Fig. 4); both have a similar "kink" in the curve at nearly the same place. This suggests an unusual relationship between the electrical conductivity and the atomic spacing, both of which depend on the magnetization. It is likely that similar behavior is found in other magnetic manganites. Understanding these properties and their relationships, may lead to improved magnetic applications.

Educational

An advanced graduate student, Lisa Downward, is working on the EXAFS studies of the manganites as part of her PhD thesis. A new graduate student, Derek Larson, has recently begun working on these materials.

Lisa, Derek, and several undergraduate students have been trained to use the XAFS technique and to run experiments at a synchrotron source. They have learned to work together as a team, and have gained hands-on experience at state-of-the-art national facilities.



Replotted from Hundley et al, Appl. Phys Lett. **67,** 860 (1995)

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